PATENT ABSTRACTS OF JAPAN

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(54) MANUFACTURING METHOD OF SILICON WAFER

(57)Abstract:
PROBLEM TO BE SOLVED: To provide the manufacturing method of a silicon wafer which is favorable for forming an annealing wafer uniformly having full zero defects layers and the BMDs density within the surface of the annealing wafer suppressing an irregularity (that is, an irregularity in defect sizes within the surface of the annealing wafer in growing condition) in the zero defects layers, which are seen in the annealing wafer subsequent to a heat treatment within the surface of the annealing wafer and an irregularity in the BMDs density subsequent to a heat treatment, such as a precipitation heat treatment or a device heat treatment, within the surface of the annealing wafer, and to provide such the silicon wafer.
SOLUTION: In the manufacturing method of a silicon wafer which forms the silicon wafer from a silicon single crystal pulled up after nitrogen is doped to the silicon single crystal by a CZ method and heat-treats the wafer, the wafer is grown on the condition that the ratio V/G of the pulling-up speed V (mm/min) at the time when the silicon single crystal is pulled up to a temperature gradient G (K/mm) in a solid-liquid interface is set in the ratio of 1 to 0.175 to 0.225 mm2/K.min in the extent wider than 90% in the radial direction of the pulled-up crystal and the wafer is formed by the manufacturing method.

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CLAIMS

[Claim(s)]
[Claim 1] In the manufacture approach of the silicon wafer which produces a silicon wafer from the silicon single crystal which doped nitrogen with the Czochrlski method and was able to be pulled up, and heat-treats to this silicon wafer the ratio of the raising rate V at the time of pulling up said silicon single crystal (mm/min), and the temperature gradient G of a solid-liquid interface (K/mm) -- V/G The manufacture approach of the silicon wafer characterized by raising on the conditions which serve as 0.175-0.225mm2 / K-min in 90% or more of range of the direction of the diameter of a pull-up crystal.
[Claim 2] the nitrogen concentration in said silicon wafer -- 1x1013-5x1015 piece/cm3 it is -- the manufacture approach of a silicon wafer of having indicated things to claim 1 by which it is characterized.
[Claim 3] The silicon wafer characterized by being manufactured by the manufacture approach indicated to said claim 1 or claim 2.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] By heat-treating to the silicon wafer produced from the Czochrlski method (CZ process) silicon single crystal which doped and pulled up nitrogen (annealing), this invention has a defect-free layer in the wafer surface section, and relates to the manufacture approach of a suitable silicon wafer to manufacture the silicon wafer (annealing wafer) with which an in thorin chic gettering (IG, Intrinsic Gettering) layer is formed in the bulk section.
[0002]
[Description of the Prior Art] The consolidation of much more integrity of a wafer surface and the gettering capacity in bulk is strongly demanded with high integration and detailed-izing of a semiconductor device. The wafer which filled two above-mentioned demands simultaneously was developed by heat-treating to it recently to the CZ process silicon wafer which doped nitrogen.
[0003] Namely, since the size of the grown-in (grown-in) defect under as-grown crystal (void defect mainly formed with the aggregate of an atomic hole) becomes small by doping nitrogen to a CZ process silicon single crystal, According to the precipitation-of-oxygen facilitatory effect which nitrogen moreover has in the bulk section by defect-free-ization of the wafer surface section becoming easy by elevated-temperature annealing of an after process By passing through precipitation heat treatment or a device heat treatment process, IG layer which has the defect (hereafter referred to as BMD (Bulk Micro Defects)) of the oxygen sludge contributed to gettering in high density is formed.
[0004]
[Problem(s) to be Solved by the Invention] By the way, it is formed in the bulk section of a CZ process silicon wafer, and having field interior division cloth is usually known, especially, a BMD consistency and the grown-in defect size of the consistency of BMD which contributes to gettering, and the size of the grown-in defect which influences formation of the defect-free layer of the surface section are large near the core of a wafer, and they have the inclination for both to fall gradually around a wafer.
[0005] This inclination is the same also in a nitrogen dope crystal, and although the absolute value of a BMD consistency or grown-in defect size changes, there is no change in having field interior division cloth. Therefore, especially after giving elevated-temperature annealing for forming a defect-free layer in the surface section, a grown-in defect will tend to remain in a part for the core of an annealing wafer.
[0006] Moreover, it became clear by examination of this invention person that the inclination for a BMD consistency to fall by the wafer periphery is remarkable about especially a nitrogen dope wafer about the BMD consistency after the precipitation heat treatment which determines the gettering capacity of bulk.
[0007] Thus, it has the problem that any property of the BMD consistency after the defect-free layer formed in the wafer surface section for which an annealing wafer is asked, precipitation heat treatment, or device heat treatment is uneven in a field at present.
[0008] Then, it is what was made in order that this invention might solve such a trouble. The variation within a field of the defect-free layer looked at by the annealing wafer after heat treatment (namely, variation within a field of grown-in defect size), The variation within a field of the BMD consistency after heat treatment of precipitation heat treatment or device heat treatment is suppressed. In order to produce the annealing wafer which has sufficient defect-free layer and a BMD consistency in the homogeneity within a field, it sets it as the main object to offer the approach and such a silicon wafer which manufacture a suitable silicon wafer.

[0009]
[Means for Solving the Problem] Invention concerning the manufacture approach of the silicon wafer of this invention of attaining the above-mentioned object In the manufacture approach of the silicon wafer which produces a silicon wafer from the silicon single crystal which doped nitrogen with the Czochrlski method and was able to be pulled up, and heat-treats to this silicon wafer the ratio of the raising rate V at the time of pulling up said silicon single crystal (mm/min), and the temperature gradient G of a solid-liquid interface (K/mm) -- V/G It is characterized by raising on the conditions which serve as 0.175-0.225mm2 / K-min in 90% or more of range of the direction of the diameter of a pull-up crystal (claim 1).
[0010] The silicon wafer cut down from the silicon single crystal which doped the nitrogen raised under such conditions can also make the field interior division cloth of grown-in defect size what also has the uniform field interior division cloth of a BMD consistency. Therefore, if elevated-temperature heat treatment is performed to this, there is no variation within a field of the defect-free layer of the wafer surface section, and the BMD consistency of the bulk section can obtain the high annealing wafer of uniform and high-density IG capacity in a field.
[0011] in this case, the nitrogen concentration in said silicon wafer -- 1x1013-5x1015 piece/cm3 it is -- things are desirable (claim 2). Since it does not have an adverse effect on training of a single crystal, either, while the effectiveness which makes size of a grown-in defect small is enough, if nitrogen concentration is dedicated within such limits, while defect-free-ization of the wafer surface section becomes easy by elevated-temperature annealing of an after process, IG layer which has BMD which contributes to gettering in high density can be formed by passing through precipitation heat treatment or device heat treatment according to the precipitation-of-oxygen facilitatory effect which nitrogen has in the bulk section.
[0012] And according to this invention, the variation within a field of the defect-free layer looked at by the annealing wafer after heat treatment and the variation within a field of the BMD consistency after heat treatment of precipitation heat treatment or device heat treatment are suppressed, and the silicon wafer which can obtain the annealing wafer which has sufficient defect-free layer and a BMD consistency in the homogeneity within a field is offered (claim 3).
[0013] Hereafter, this invention is further explained to a detail. this invention person did the knowledge of preparing that in which neither the consistency of BMD which contributes to the gettering formed in the bulk section as a silicon wafer, nor the size of the grown-in defect which influences formation of the defect-free layer of the surface section has field interior division cloth, in order to produce the annealing wafer which has sufficient defect-free layer and a BMD consistency in the homogeneity within a field.
[0014] That is, this invention person investigated wholeheartedly about the grown-in defect consistency of the wafer surface section after giving elevated-temperature annealing to the CZ process silicon wafer which is carrying out actual condition manufacture as an object for annealing wafers and by which the nitrogen dope was carried out, and the BMD consistency after additional ****. Consequently, although there were many residual defects and its BMD consistency was also high in the wafer core, in the wafer periphery, the number of residual defects was understood that it is few and there are also few BMD consistencies. Moreover, the middle location (henceforth R/2 location) R also had few residual defects moderately in the wafer radius, and the BMD consistency was also high moderately.
[0015] In these three places, the integrity of the surface section and the balance of the gettering capacity in bulk will have R/2 best location. That is, if the condition of this R/2 location is expandable in a wafer side, a uniform and quality wafer will be obtained in a field. Then, in order to expand the condition of this R/2 location, the correlation with an approach to pull up distribution of BMD or a grown-in defect and a CZ process silicon single crystal was investigated.
[0016] Consequently, as for the cause by which the field interior division cloth of grown-in defect size or a BMD consistency becomes an ununiformity in this way, V/G which is the ratio of the temperature gradient G (K/mm) of the solid-liquid interface of the raising shaft orientations in the range from the pull-up rate V at the time of crystal training (mm/min) and the melting point of silicon to 1400 degrees C at least had distribution in the field, namely, it has turned out that it is to change V/G in a field. Then, it decided to calculate concrete V/G value required in order not to be concerned with the location within a wafer side but to make grown-in defect size and a BMD consistency into a desired thing. Hereafter, this is explained.
[0017] Since it is already known well that a grown-in defect will be influenced of V/G the specific hot zone (it

Zone(s) and HZ(s) Hot [ ] --) of crystal pulling equipment It is the nitrogen concentration incorporated during a pull-up crystal using the structure in a furnace 1x1013 pieces/cm 3 It carries out. The crystal of two or more was raised at the pull-up rate chosen from the range of 1.0 - 1.4 mm/min, and the relation between the relation between the field interior division cloth of each V/G and the size of a grown-in defect and the BMD consistency after heat treatment of 800 degree-Cx4-hour +1000-degree-Cx 16 hours was investigated. The result is shown in drawing 1 and drawing 2 .
[0018] It means that drawing 1 shows the relation of all the data of a BMD consistency and V/G which were measured about a center section, the R/2 section within the field of a wafer, and a periphery (it is the location of 10mm from a wafer periphery), and the BMD consistency correlates it V/G and directly. 1x109 which will become inadequate [gettering capacity] if less [if V/G becomes smaller than 0.190mm2 / near K-min, a BMD consistency will fall rapidly, and] than 0.175mm2 / K-min An individual / cm3 It turns out that it falls to below. That is, in order to obtain BMD of high density, V/G was understood [more than 0.175mm2 / K-min, then] are good irrespective of the location within a wafer side.
[0019] On the other hand, drawing 2 makes relative evaluation on the size of a grown-in defect by OPP (Optical Precipitate Profiler), and shows the result of having investigated relation with V/G. The relation of all the data of OPP size and V/G which were measured like drawing 1 about a center section, the R/2 section within the field of a wafer, and a periphery is shown, and it means that OPP size correlates V/G and directly. That is, in the range in which the size of a grown-in defect exceeds 0.225mm2 / K-min by V/G becoming small rapidly by below 0.225mm2 / K-min, it discovered newly that the size of a grown-in defect was in a saturation inclination with a big value. Therefore, what is necessary is not to be concerned with the location within the field of a wafer, but just to make V/G into below 0.225mm2 / K-min, in order to consider as a grown-in defect with the small size which is easy to extinguish by heat treatment.
[0020] As mentioned above, if V/G is manufactured so that it may become within the limits of 0.175-0.225mm2 / K-min in the direction of a path of a crystal in case the CZ process silicon single crystal by which the nitrogen dope was carried out is pulled up from the result of drawing 1 and drawing 2 , an ununiformity does not become in a wafer side, but since grown-in defect size is moderately small, the annealing wafer with which a grown-in defect is extinguished all over a wafer in rear-spring-supporter 10 minutes, and a moderate BMD consistency is formed will be obtained.
[0021] Here, in the periphery section of a pull-up crystal, the point defect which determines the size and the BMD consistency of a grown-in defect will carry out out-diffusion during crystal training. Therefore, in the field (when a crystal with a diameter of 200mm is pulled up, it is from a periphery edge to 10mm) from the periphery edge of a pull-up crystal to about 5% of a radius, correlation of the size and the BMD consistency of a grown-in defect, and V/G becomes weak. Namely, it is at least 90% of field except every 5% of both periphery sections of the direction of a path of a pull-up crystal that V/G in this invention is applied, and this field is changed in 90 - 100% of range according to pull-up conditions.
[0022]
[Embodiment of the Invention] Hereafter, the operation gestalt of this invention is explained to a detail, referring to a drawing. First, drawing 6 R> 6 explains the example of a configuration of the crystal pulling equipment by the CZ process used by this invention. As shown in drawing 6 , this crystal pulling equipment 30 The pull-up room 31, the crucible 32 prepared all over the pull-up room 31, and the heater 34 arranged around a crucible 32, It has the reel style (not shown) which rotates or rolls round the crucible maintenance shaft 33 made to rotate a crucible 32 and its rolling mechanism (not shown), the seed chuck 6 holding the seed crystal 5 of silicon, the wire 7 that pulls up a seed chuck 6, and a wire 7, and is constituted. A quartz crucible is prepared in the side in which a crucible 32 holds the silicon melt (molten bath) 2 of the inside, and the graphite crucible is prepared in the outside. Moreover, the heat insulator 35 is arranged around [outside] the heater 34.
[0023] Moreover, what is necessary is just to perform the approach of expanding the proper range of V/G to the direction of a path, and shaft orientations as manufacture conditions in connection with the manufacture approach of this invention, by the approach already learned well. That is, the annular solid-liquid interface heat insulator 8 is formed in the periphery of the solid-liquid interface of a crystal, and HZ which has arranged the up surrounding heat insulator 9 is installed on it so that the difference (germanium-Gc) of the temperature gradient (germanium) of the crystal circumference and the temperature gradient (Gc) of a crystal center may be made small and the solid-liquid interface temperature gradient G may become a flat in a field. This solid-liquid

interface heat insulator 8 forms the 3-5cm clearance 10 between that soffit and surface of hot water of silicon melt 2, and is installed in it. The up surrounding heat insulator 9 may not be used depending on conditions. Furthermore, coolant gas may be sprayed or the tubed cooling system 36 which interrupts radiant heat and cools a single crystal may be formed.

[0024] Independently, by installing the magnet which is not illustrated in the horizontal outside of the pull-up room 31, and impressing magnetic fields, such as a horizontal direction or a perpendicular direction, to silicon melt 2, the convection current of melt is controlled and, recently, the so-called MCZ method for measuring the stable growth of a single crystal is used in many cases.

[0025] Next, the single-crystal-growth approach by above crystal pulling equipment 30 is explained. First, within a crucible 32, the high grade polycrystal raw material of silicon is heated more than the melting point (about 1420-degreeC), and is dissolved. A nitrogen dope can be performed by throwing in a silicon wafer with a nitride for example, in raw material silicon. Next, the head of seed crystal 5 is made contacted or immersed in the surface abbreviation core of melt 2 by beginning to roll a wire 7. Then, while rotating the crucible maintenance shaft 33 in the proper direction, single crystal growth is started by rolling round rotating a wire 7 and pulling up seed crystal 5. Henceforth, the single crystal rod 1 of an approximate circle column configuration can be obtained by adjusting a pull-up rate and temperature appropriately.

[0026] It can consider as a nitrogen dope silicon wafer by cutting down the obtained single crystal rod by a wire saw etc. by the usual approach, and giving beveling, wrapping, etching, polish, etc.

[0027] Next, in this invention, it heat-treats to the obtained silicon wafer. A defect-free layer is formed in a front face of this at the homogeneity within a field, and BMD occurs in high density by it at the bulk section. Heat treatments (for example, 1150 degree C, 4 etc. hours, etc.) of 1 hours or more are performed at 1000-1350 degrees C under inert gas, such as an argon, hydrogen gas, or these mixed ambient atmospheres, using the batch type furnace of the usual heater type as concrete heat treatment conditions. Moreover, using the RTA (Rapid Thermal Annealing) equipment by lamp heating etc., heat treatment by rapid heating and forced cooling can be performed, or it can also consider as heat treatment which used together a batch type furnace and RTA equipment.

[0028]

[Example] Although the example and the example of a comparison of this invention are given and this invention is explained concretely hereafter, this invention is not limited to these.

(Example 1) as an example 1 -- crystal center temperature gradient Gc= -- 3.543 [K/mm] and crystal ambient temperature inclination germanium= -- 3.933 [K/mm] and germanium-Gc= -- using 0.390 [K/mm] and the crystal pulling equipment which has HZ with comparatively small germanium-Gc, the pull-up rate was adjusted to about 0.74 mm/min, and the nitrogen dope silicon single crystal with a diameter of 6 inches was pulled up. A nitrogen dope throws in a silicon wafer with a nitride in raw material silicon, and the nitrogen concentration (calculated value) in the location of the shoulder of a pull-up crystal is 2x1013-/cm3. It was made to become. Moreover, the oxygen density was adjusted so that it might be set to 14 - 15ppma (JEIDA (Japan Electronic Industry Development Association) specification).

[0029] The crystal radial distribution of V/G at the time of crystal pulling were shown in drawing 3 . As for V/G, the whole close direction of a path was in the range of about 0.180-0.223mm2 / K-min.

[0030] the crystal which was able to be pulled up to a silicon wafer -- producing -- OPP -- the precipitation heat treatment of 4-hour 800 degrees C after measuring the size of a grown-in defect by law and +1000 degrees C, and 16 hours -- adding -- BMD -- forming -- OPP -- the BMD consistency was measured by law. The measurement result of the size of a grown-in defect was shown in drawing 4 , and the measurement result of a BMD consistency was shown in drawing 5 .

[0031] The grown-in defect was the size (1.5 or less) which can fully be extinguished according to 1200 degrees C and the argon ambient atmosphere of 1 hour (drawing 4), and was small. [of field interior division cloth] moreover, a BMD consistency -- the inside of a wafer side -- which location -- also setting -- about two to 5x109-/cm3 it is -- high-density and uniform field interior division cloth was obtained (drawing 5).

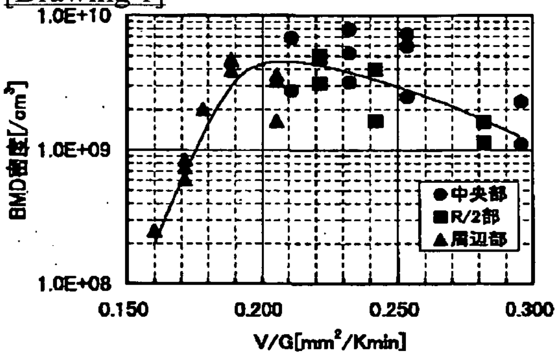
[0032] (The example 1 of a comparison, example 2 of a comparison) as the examples 1 and 2 of a comparison -- Gc= -- 3.778 [K/mm] and germanium= -- 4.904 [K/mm] and germanium-Gc= -- using 1.126 [K/mm] and the crystal pulling equipment which has HZ with comparatively large germanium-Gc, in the example 1 of a comparison, the raising rate was adjusted to about 0.87 mm/min in about 0.84 mm/min and the example 2 of a

comparison, and the nitrogen dope silicon single crystal with a diameter of 6 inches was pulled up. A nitrogen dope throws in a silicon wafer with a nitride in raw material silicon, and the nitrogen concentration (calculated value) in the location of the shoulder of a pull-up crystal is 2x1013-/cm3. It was made to become. Moreover, the oxygen density was adjusted so that it might be set to 14 - 15ppma (JEIDA).
[0033] The crystal radial distribution of V/G at the time of the crystal pulling of the example 1 of a comparison and the example 2 of a comparison were written together to drawing 3 . It was about 83% from the core of a crystal to the range of about 62mm that close V/G was in the range of 0.175-0.225mm2 / K-min in the example 1 of a comparison, and, in the case of the example 2 of a comparison, it was about 48% from the location of about 30mm to the location of about 66mm in the direction of a periphery from the core of a crystal.
[0034] the crystal which was able to be pulled up to a silicon wafer -- producing -- OPP -- the precipitation heat treatment of 4-hour 800 degrees C after measuring the size of a grown-in defect by law and +1000 degrees C, and 16 hours -- adding -- BMD -- forming -- OPP -- the BMD consistency was measured by law. To drawing 4 , the measurement result of the size of a grown-in defect was written together, and the measurement result of a BMD consistency was written together to drawing 5 .
[0035] In the example 1 of a comparison, grown-in defect size was small to some extent, and it was very small in a wafer periphery at the wafer core side, and although just the field interior division cloth of defective size was large, it was the defect of the size which is easy to disappear by annealing on the whole. However, about the BMD consistency after precipitation heat treatment, it sets to a wafer periphery with the low value of V/G, and a BMD consistency is 2x108-/cm3. It is low with extent and it turned out that field interior division cloth with small gettering capacity is large at a periphery.
[0036] In the example 2 of a comparison, it is related with a BMD consistency, and is about 1x109-/cm3 in a field. Although the above was obtained, the field interior division cloth of grown-in defect size was large, and since the size by the side of a wafer core was quite large, even if it performed annealing by 1200 degrees C and the argon ambient atmosphere of 1 hour, it checked especially that a part of grown-in defect for a core remained.
[0037] In order to make the size of a grown-in defect, and the both sides of a BMD consistency into the homogeneity within a field in HZ of the crystal pulling equipment used in the examples 1 and 2 of a comparison, these results will show that it is very difficult, even if it controls a pull-up rate in the range in which it was restricted to 0.84 - 0.87 mm/min.
[0038] In addition, this invention is not limited to the above-mentioned operation gestalt. The above-mentioned operation gestalt is instantiation, and no matter it may be what thing which has the same configuration substantially with the technical thought indicated by the claim of this invention, and does the same operation effectiveness so, it is included by the technical range of this invention.
[0039] For example, in the above-mentioned operation gestalt, although the example was given and explained per when a silicon single crystal with a diameter of 6 inches was raised, this invention is not limited to this but can be applied also to the diameter of 8-16 inches, or the silicon single crystal beyond it. Moreover, it cannot be overemphasized that this invention is applicable also to the so-called MCZ method for impressing a level magnetic field and length magnetic field, a cusp field, etc. to silicon melt.
[0040]
[Effect of the Invention] According to this invention, the field interior division cloth of grown-in defect size can also form the silicon wafer which doped nitrogen also with the uniform field interior division cloth of a BMD consistency. Therefore, if elevated-temperature heat treatment is performed to this, there is no variation within a field of the defect-free layer of the wafer surface section, and the annealing wafer with which a BMD consistency has uniform IG layer in a field in the bulk section can be manufactured.

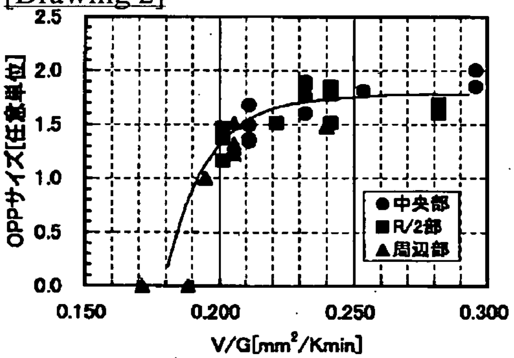
[Translation done.]

DRAWINGS

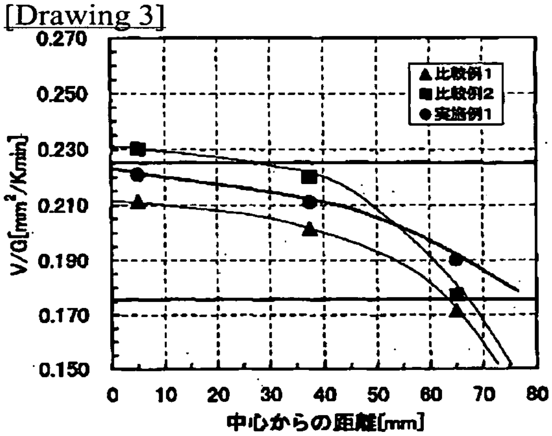
[Drawing 1]



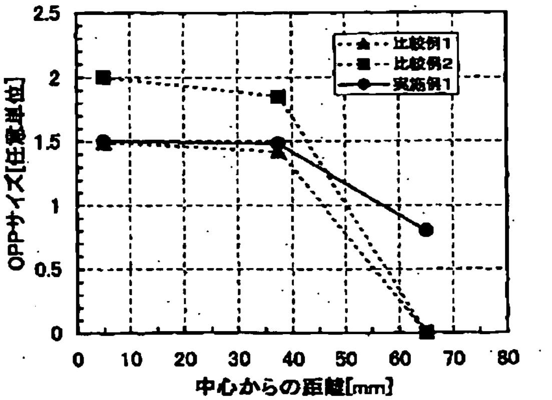
[Drawing 2]



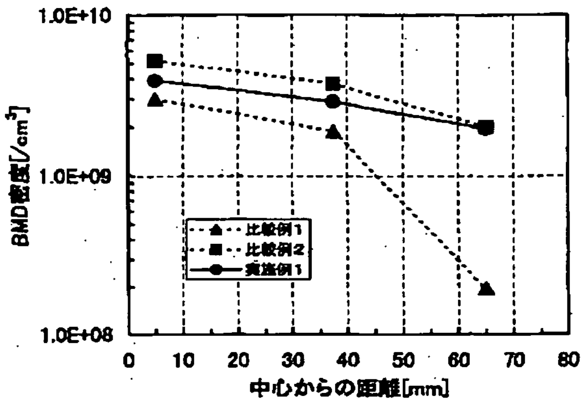
[Drawing 3]



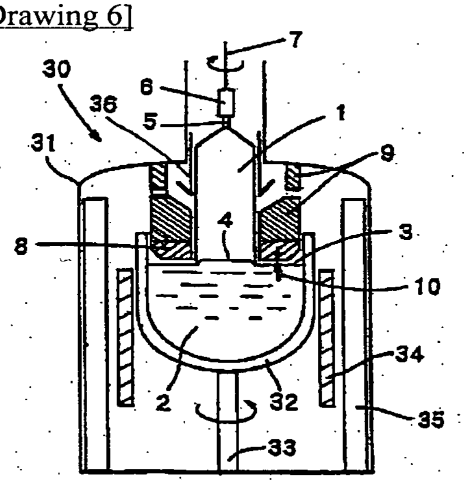
[Drawing 4]



[Drawing 5]



[Drawing 6]



[Translation done.]